REMARKS/ARGUMENTS

Rejection of Claims 1-38

The Examiner rejects claims 1-38 under 35 U.S.C.§103(a) as being unpatentable over Sugden (U.S. Patents 4,548,442) in view of Lauber (U.S. 3,415,574), Ford et al. (U.S. 4,531,782), or Schwoebel et al. (U.S. 6,612,655) and over Smith et al. (U.S. 6,062,650) in view of Lauber, Ford et al., or Schwoebel et al. The cited references fail to teach or suggest at least the following italicized features of independent claim 1:

> 1. An excavator, comprising:
> a boom;
> a cutter head, mounted on the boom, for excavating in situ material;
> a body, wherein the boom is mounted on the body;
> a plurality of grippers operable to apply pressure against opposing surfaces of an excavation to hold the body in a selected position and orientation; and
> a control system operable to effect operation of the excavator *both* (a) in a manual mode in which an operator controls operation of the boom and/or cutter head and the plurality of grippers and (b) an automatic mode in which the control system controls operation of the boom and/or cutter head and the plurality of grippers, *wherein the control system comprises a task supervisor, the task supervisor is configured as an engine that invokes at least one of a plurality of state machines to perform a selected unit operation and wherein the plurality of state machines correspond to a plurality of a mining state in which in situ material is excavated, a walking state in which the excavator is repositioned for the mining state, a boom sweep state in which the boom is moved, a steering state in which an orientation of the excavator is changed, and a self-test state in which a configuration of the excavator is compared against a predetermined configuration.*

The present invention is directed to a control system for a fully automated excavation machine. The control system invokes one or more state machines to cause a desired operation to be performed. The possible state machines include mining, walking, steering, self-test, single boom sweep state, continuous boom sweep state, and a thrust (advance) state. Each state

machine is a software algorithm that uses various inputs and suitable logic to perform the desired set of operations.

Compared to prior art automated excavators, the excavator of Claim 1 can move in a predictable fashion in response to operator commands. This is so because the excavator uses a task supervisor engine and collection of state machines rather than a non-determinisitic or "chaotic" algorithm, such as neural networks or fuzzy logic. An engine invoking multiple state machines can also provide a much simpler and more efficient architecture.

<u>Sugden</u>

U.S. 3,415,574 to Sugden is directed to a tunnel driving system including a tunnel driving machine adapted to be guided by the walls of a tunnel being driven, a steering device including a self-contained unit, and towing means detachably connecting the steering device as a trailer to the tunnel driving machine. The rear end of the tunnel driving machine has a rearwardly extending trunnion, which is adjustable in two different directions which are normal to the axis of the trunnion and at an angle to each other. The steering device includes adjusting means engaging the trunnion and are operable to adjust the trunnion in the two directions.

Sugden discloses a pushbutton control system for generating position adjustment commands, with a first pair of pushbuttons being for one movement, e.g., horizontal, and a second pair of pushbuttons being for another movement, e.g., vertical. Additionally, an automatic control is provided for positional adjustment of the excavator. A gyro compass indicates deviations of the direction of the machine so that the deviation of the direction can be corrected by a surface integrator. The integrator and control circuitry convert the deviations from

the selected course into control commands for switching the motors for driving the actuators so that steering is fully automatic.

Regarding automated operation, Sugden, et al., states at col. 16, lines 20-53:

> To start a tunnel, the operator crawls the machine 500 up to the rock face 552 (FIG. 7) until the cutterhead 502 just touches the rock face midpoint 554. The floor jacks are then extended to elevate the machine to grade as determined by a laser. The onboard mini-computer is input with machine position and the cutterhead 502 is advanced a small amount into the rock. The operator then energizes the start sequence and the cutterhead 502 cuts any of several *preprogrammed* profile shapes, for example, the dome-shaped profile shown in FIG. 9 which is designed to receive the ring beams 598. The computer controls the boom movement during the cutting cycle in response to linear transducers which measure the excursion of the boom in the horizontal axis and the vertical axis. Alternatively, manual controls may be used.
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> After the cutting cycle is complete, the *operator* advances the machine 500 into the rock and again presses the start button. After completing a series of cutting cycles and reaching the end of a thrust stroke, the operator raises the floor jacks, crawls forward a short distance (e.g., 75 cm) and extends the jacks to begin a new series of cutting cycles. After the machine has advanced approximately 7 meters into a new rock face, the grippers 530a and 550b are extended for drilling support.
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> The hydraulic control system for the mobile mining machine 500 may be similar in principle to the hydraulic control system of the mobile mining machine 10 shown in the simplified schematic representation of FIGS. 5A, 5B, and 5C.
>
> The cutter profile of the mobile mining machine 500 may be similar in principle to the cutter profile of the mobile mining machine 10 shown in FIG. 12.

(Emphasis supplied.) As can be seen from the above language, Sugden, et al., says nothing about a task supervisor configured as an engine that invokes at least one of a plurality of state machines to perform a selected unit operation.

<u>Smith et al.</u>

U.S. 6,062,650 is directed to a mining machine control system including a first angular encoder for continuously measuring the tilt angle of the boom, a second angular encoder for continuously measuring the angle of rotation of the turret, a linear encoder for continuously measuring linear position of the cutter head, and a controller controlling proportional valves. The valves control flow of hydraulic fluid into a hydraulic cylinder, the speed of rotation of the turret as well as the linear advance of the cutter head. In this manner, the controller continuously controls the boom angular position, the angular position of the turret, and the linear position of the cutting head so as to cut a preselected profile at a predetermined depth of cut and rate of advance.

In the automated control system, the control of the cutting head 14 is implemented using: a first angular encoder 40 at the bottom of the boom pivot 22 to continuously measure the tilt angle of the boom 12; a second angular encoder 44 at the end of the shaft 45 to continuously measure the rotating angle of the turret 20; a linear encoder 55 to continuously measure the linear position of the housing 42 and the cutting head 14; pressure transducers P_1 and P_2 to continuously measure the pressure at each end of the hydraulic drives 41 and 43; pressure transducers P_3 and P_4 to continuously measure the pressure at each end of sumping cylinders 62 and 64; and power transducer 57 to measure the power input to motor 18 which drives the head 14. Additionally, the speed of rotation of the cutting head 14 is controlled through variable speed drive 74, boom vibration and/or frequency can be measured and controlled by accelerometer 80, tool temperature

may be measured and controlled by thermocouples, and tool force may be measured and controlled using strain gauges.

The '650 patent fails to teach or suggest manual operation of the mining machine let alone the use of a task supervisor configured as an engine that invokes at least one of a plurality of state machines to perform a selected unit operation.

These deficiencies are not overcome by the remaining references.

Lauber

Lauber is directed to a tunnel driving machine having a steering device, including a self-contained unit, which is independently supported in the tunnel and disposed behind the tunnel driving machine and is detachably connected to it by towing rods or the like, and the tunnel driving machine is provided at its rear end with a preferably central trunnion, which extends rearwardly and is held in the steering device for adjustment in two directions, which are at an angle to each other and normal to the axis of the trunnion. Steering may be effected by a self-holding push button control system for generating the adjusting commands, with a first pair of push buttons being for one movement and another pair for the other movement.

The only discussion of an automated system is as follows:

> When switching from automatic steering to manual steering is enabled, the operator of the machine may steer by a direct actuation of the pushbuttons. In the case of automatic steering, the adjusting commands required for steering along an arc or a pregiven curve may be stored as a program in the electronic control circuitry.

(Col. 3, lines 15-21.)

As can be seen from the above language, Lauber says nothing about a task supervisor configured as an engine that invokes at least one of a plurality of state machines to perform a selected unit operation.

Ford et al.

Ford et al. is directed to mining equipment for steering the cutting horizon of a mining machine cutter which is mounted on a ranging arm and which in use makes repeated traverses along the working face. The equipment comprises a boom urged into contact with the mine roof formed on a previous traverse of the machine. The boom is urged towards the mine roof by a ram hydraulically connected to a piston and cylinder device such that movement of the piston of the device is in accordance with that of the ram. Movement of the piston rod activates a flow control valve controlling operation of a ram controlling ranging of the arm.

The excavator includes a sensor for determining a thickness of the hanging wall and logic for controlling the rams to maintain the machine's cutting horizon at a desired level within the coal seam and an element 42 and roller 46 for controlling pivotal movement of the ranging arm 1 to vary the cutting horizon of the cutter drum 2. The sensor may be a probe for detecting gamma radiation emitted from overlying strata and attenuated by its passage through the roof layer. Alternatively, the sensor may include a source and detector of radiation or of a sonic, ultra sonic signal, sonic or radar.

Regarding automated control, Ford, et al., simply states that "[t]he derived signal [from the sensing means] is fed to steering control means (not shown) which control the rams to maintain the machine's cutting horizon and a desired level within the mineral seam." (Col. 2, lines 40-55.)

As can be seen from the above language, Ford, et al., says nothing about a task supervisor configured as an engine that invokes at least one of a plurality of state machines to perform a selected unit operation.

<u>Schwoebel et al.</u>

U.S. 6,612,655 to Schwoebel et al. is directed to a method and apparatus for cutting a borehole substantially in the shape of a bread loaf within a mine. The method and apparatus includes four cutting systems. The first cutting system is a pair of three-armed, counter rotating, cutting heads which remove material from the mine face in a substantially vertical plane. The second cutting system is a pair of rotating cutting drums which follow the pair of counter rotating cutting heads. The third cutting system is a substantially vertical, rotating cutting head which removes the kerf formed at the ceiling or roof portion of the borehole. The fourth cutting system is a plow which both removes the kerf at the bottom of the borehole and directs the mined material to a conveyor system to remove the mined material from the mine.

Schwoebel et al. discloses a control system at Fig. 7 and col. 7, line 29, to col. 8, line 55. The control system uses various inputs, such as the force on the mechanical bits, the flow of water through the high pressure water jet assemblies 60, the operation of the various motors which operate the four cutting systems (e.g., motor operational parameters include the rpm of the

motor, the temperature of the motor, the temperature of any oil used to lubricate the motor, and the power or amount of amperage being used to run the motor), the position of the apparatus 10 within the borehole 1000 of the mine, feedback on the material being mined (e.g., using ground penetrating radar which enables the controller 650 to receive inputs as to where the material to be mined is located with respect to the various cutting systems), the amount of methane in the mine, the amount of carbon monoxide, the amount of carbon dioxide, and the air flow rate within the mine, the speed of the conveyor and the electrical power being supplied to the motor which drives the conveyor 450, the speed of each one of the two endless chain crawlers 552, the power provided to the motors for moving the endless chain crawlers 552, and video and audio feed, and control logic (which is not explained) to control automatically the excavating machine.

Regarding the automated control and operation, Schwoebel, et al., states:

> As may be seen in FIG. 7, the computer based controller 650, which is the third cutting support system, includes three portions. The first portion, shown on the top of FIG. 7, is an input system which senses operating conditions within the mine. The second portion, shown in the middle of FIG. 7, is a processing portion which receives and analyzes the information received from the various inputs into the controller 650. And the output portion, shown on the bottom of FIG. 7, is the system which provides signals to the operating portions of the apparatus 10 and also to the control or monitoring function which normally takes place well above the borehole at ground level. In the instant invention, the processing of information may take place within the mine, on the surface, or a combination of both.
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> . . .
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> The controller 650 is built around a central computer which receives the various inputs which have been described above. The information received from the various inputs is processed to provide outputs to govern the operation of the apparatus 10. This information may also be used to feed information into a diagnostic program which will determine if there are any problems with the operation of the apparatus 10 and automatically correct those problems. In the case of a severe or problematic condition, the controller will also include systems to provide a warning of a dangerous condition to the

> operators remotely positioned away from the mining operations, and even possibly shut down the apparatus 10 in the event of a severely dangerous or hazardous condition such as a fire.
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> The output of the controller 650 not only provides monitoring of the operation of the apparatus 10 to the operators who may be positioned a significant distance away on the surface, but may also allow manual overrides to various control parameters. While the control parameters are generally designed to be automatic; that is, the controller 650 will sense what needs to be done for efficient mining and make appropriate corrections in its position and operation, it will be possible to manually override such automatic control. Automatic feedback will be provided to the various different cutting systems, as well as to the tramming or positioning system 550 to assure that the apparatus 10 moves forward and tracks into the mine face 1050. Additionally, and as previously indicated, the speed of the conveyor 450 will be controlled such that it is sufficient to always move mined material away from the mine face 1050 and out of the borehole 1000 at a rate which is faster than the rate at which the cutting systems are producing mined material.

(Col. 7, line 30 to col. 8, line 55.)

Although Schwoebel, et al., does discuss automated operation of an excavator, it fails to provide details on how such automation is effected. As can be seen from the above language, Schwoebel, et al., says nothing about a task supervisor configured as an engine that invokes at least one of a plurality of state machines to perform a selected unit operation.

Simply put, none of the references, taken individually or collectively, teach or suggest the use of a task supervisor configured as an engine that invokes at least one of a plurality of state machines to perform a selected unit operation

Accordingly, the pending claims are allowable over the cited references.

The dependent claims provide additional reasons for allowance. For example, the various references fail to teach the use of the task supervisor to set the excavator to continuous boom and single boom sweep states (the '650 patent, at col. 4, lines 14-17, and col. 9, lines 41-45, teaches

away from a single boom sweep state) (claim 4), the use of pressure control and position control functions in hydraulic cylinders (claims 6-7 and 21), the conversion of hydraulic pressure readings into torque (claim 10), the incremental steps of claim 13, an optimization module (claims 17-18), a swing angle optimization module (claim 19), the use of an end of stroke sensor and pressure and/or force sensors to determine whether actuators are or are not locked into position against an excavation surface (claims 20 and 36), roll and pitch automated adjustment algorithm (claims 22-23), the positional sensor of claim 27, the emergency retract line of claim 30, and the predefined fault response state of claims 34-35.

<u>Rejection of Claims 60-64</u>

The Examiner rejects claims 60-64 as being anticipated by U.S. Patents 4,548,442 or 6,062,650. The cited references fail to teach or suggest at least the following italicized features of independent claim 60:

> 60. An excavator, comprising:
> a boom;
> a cutter head, mounted on the boom, for excavating in situ material;
> a body;
> a plurality of grippers operable to apply pressure against opposing surfaces of an excavation to hold the body in a selected position and orientation; and
> *an optimization module operable to monitor a selected excavation parameter and effect a change in the operation of the cutter head when the monitored selected excavation parameter one of exceeds or falls below a predetermined threshold, wherein the selected excavation parameter is at least one of:*
> *(i) a grade of a material removed during cutter head operation; and*
> *(ii) a quantity of material removed during cutter head operation.*

U.S. Patents 4,548,442; 3,415,574; and 6,062,650 fail to teach or suggest monitoring the material during excavation let alone an optimization module.

At col. 2, lines 40-55, U.S. Patent 4,531,782 states as follows:

> The mining machine of FIGS. 1 to 5 may be provided with sensing means for detecting the cutting horizons of the cutter drum *with respect to the mineral seam.* These sensing means may comprise a device for detecting the *thickness of roof mineral* left by the machine on the immediately proceeding mine roof cutting traverse and for deriving a signal indicative of the sensed thickness. The derived signal is fed to steering control means (not shown) which control the rams to maintain the machine's cutting horizon and a desired level within the mineral seam. *Such sensing means may comprise, for example, a probe for detecting natural gamma radiation emitted from the overlaying strata and attenuated by its passage through the roof layer. Alternatively, the sensing means may comprise a source and detector of radiation or of a sonic, ultra sonic signal, sonic or radar.*

(Emphasis supplied.)

As can be seen from the above, the above language, the sensing means senses the thickness of the material in the overlying layer. It does not sense the grade of the *in situ* coal seam, the grade of the *removed* coal, or the quantity of material *removed.*

Schwoebel, et al., teaches the sensing of *in situ* formations by noting differences in the cutting resistance between softer minerals, such as coal and harder rock strata and/or by using ground penetrating radar to locate where the material to be mined is located with respect to various cutting systems. (Col. 7, line 56, to col. 8, line 3.) Like Ford, et al., Schwoebel, et al., fails to teach the grade of the *in situ* coal seam, the grade of the *removed* coal, or the quantity of material *removed.* Rather than measuring grade, it simply locates the coal seam.

The dependent claims provide additional reasons for allowance.

Based upon the foregoing, Applicants believe that all pending claims are in condition for allowance and such disposition is respectfully requested. In the event that a telephone conversation would further prosecution and/or expedite allowance, the Examiner is invited to contact the undersigned.

Respectfully submitted,

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